Soiling Persistence Model as Benchmark for Soiling Forecasts of Solar Collectors

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Motivation and Objective

- Forecasting soiling levels allows the optimization of the trade-off between the reduction of soiling losses and cleaning costs of photovoltaic (PV) power plants.
- Several models can be used to generate soiling forecasting (e.g., [1,2]), yet comparing performances across approaches is difficult.
- A soiling rate persistence model is presented to be used as benchmark for other soiling forecasting models.

Soiling Persistence Model

The model assumes that the daily rate at which the soiling builds up (the soiling loss rate, *SLR)* remains the same across the entire forecast horizon, unless a manual or natural cleaning event occurs.

Estimation of SLR with moving average

- SLR at time t_0 is the average SLR of the last k days before day t_0 (Figure 1).
- Several values for k are tested.

Natural cleaning by rain

- If daily rain sum is larger than 6 mm (default threshold taken from [2], see discussion in [3]), a complete cleaning of the PV modules is assumed. Otherwise, no natural cleaning is assumed.
- The model is implemented with and without natural cleaning.
- Precipitation forecasts are assumed to be perfect for this study and hence taken from measurements on site.

→ For the evaluation, the persistence model is compared with the state-of-the-art Kimber soiling model [2].

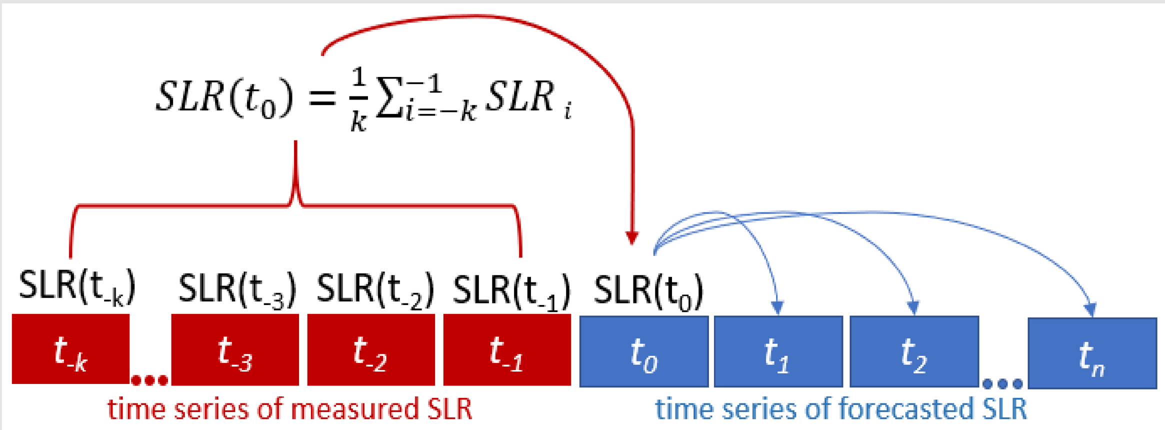

Figure 1: Scheme of the soiling loss rate persistence model

Figure 2: Left: IRESEN's Green Energy Park in Ben Guerir, Morocco. *Right: PVot Testbench at CIEMAT's Plataforma Solar de Almería*, Spain

Measurement Data

Daily rain sum and *soiling ratio (SR)* measurements from:

- a Kipp&Zonen DustIQ sensor at IRESEN's Green Energy Park (GEP) in Ben Guerir, Morocco
- reference cells at CIEMAT's Plataforma Solar de Almería (PSA), Spain

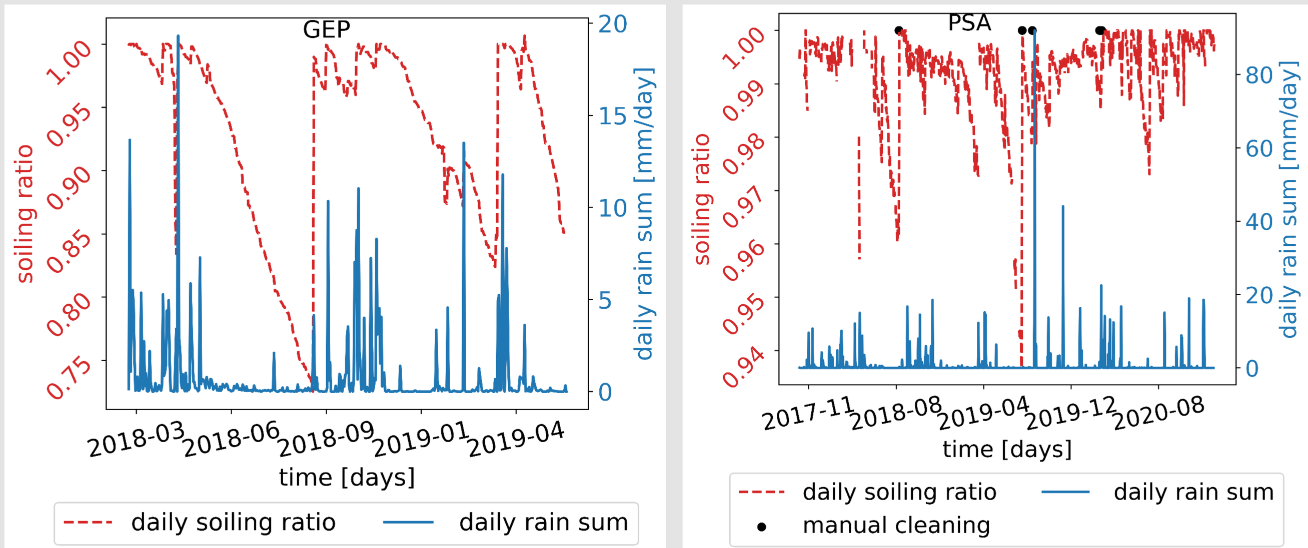

Figure 3: Left: Daily *SR* and rain sum measurements at the GEP (Morocco) between March 2018 and June 2019. Right: Measurements at the PSA (Spain) between December, 2017 and January, 2021

Results

Persistence model with and without considering rainfall

- In both sites the persistence model considering rainfall results in lowest error metrics for nearly all lead times (Figure 4).
- When natural cleaning is not considered the persistence model drastically underestimates the SR.

Kimber model vs. persistence model

GEP:

- RMSD and MAD: the persistence model considering rainfall outperforms the Kimber model at short lead times. Depending on the value of k and the error metric, the persistence model excels from lead times between 3 and 31 days.
- Bias: the persistence model outperforms the Kimber model also for higher lead times and even at all lead times for k equal to 1 and 5.

PSA:

- The persistence model outperforms the Kimber model at all lead times for most values of k.

→ Extreme soiling events at the GEP (see Figure 3) lowers the performance of the persistence model in comparison to the PSA.

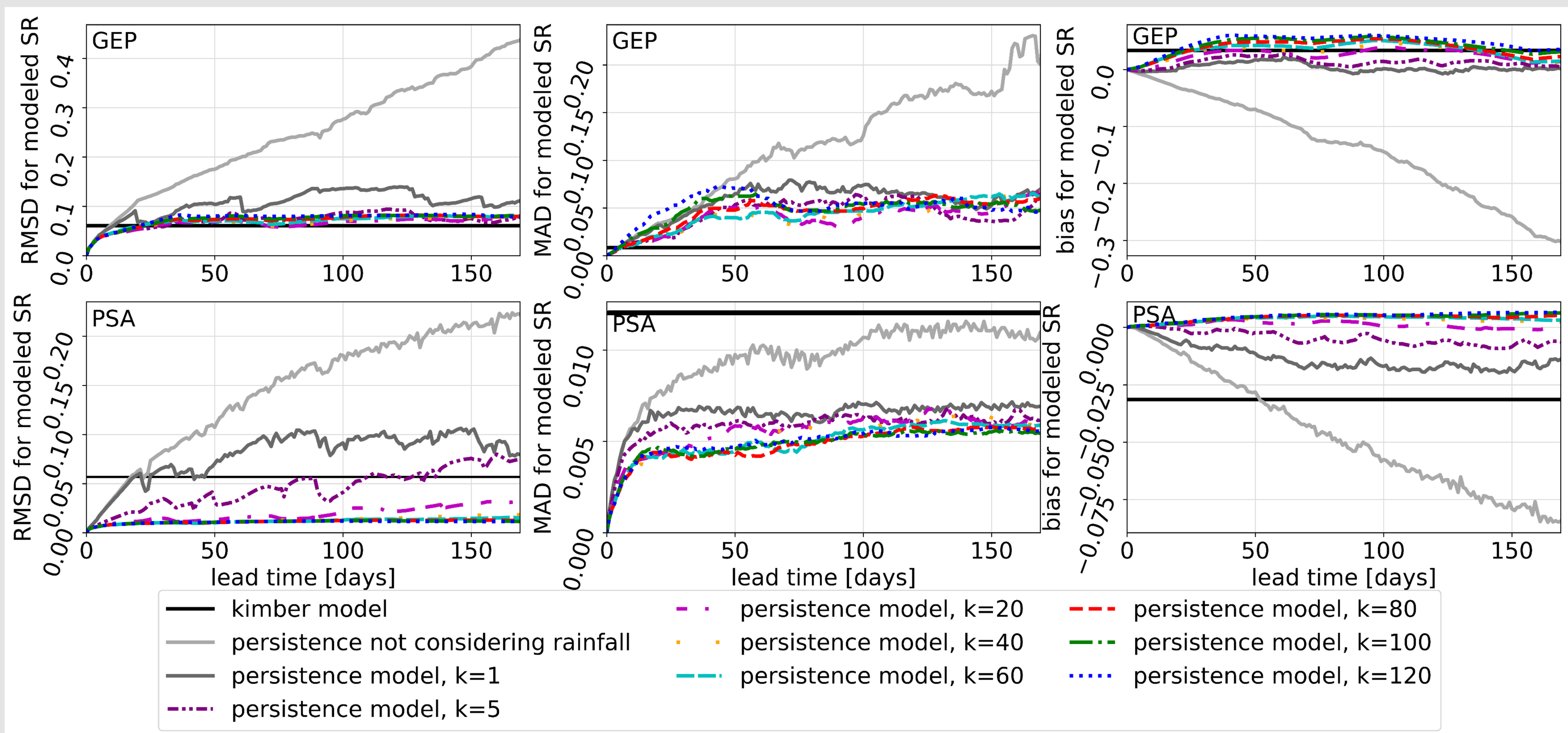

Figure 4: RMSD, MAD, and bias of the Kimber model and the persistence model with (for several k values) and without (for k equal to 1) consideration of rainfall for all lead times up to 170 days (upper plots: GEP, lower plots: PSA)

Persistence model with precipitation for different k

Improvement of persistence model performance using moving averages (*k* between 1 and 120) to calculate the SLR (Figure 5).

GEP:

- RMSD and MAD smallest for k equal to 20.
- Bias increases with increasing k values.
- Values of k from 10-20 seem to be a good recommendation.

PSA:

- RMSD decreases with increasing k values.
- From k higher than 40, RMSD stagnates at around 0.011.
- MAD has minimum for k equal to 80.
- Bias is closest to zero for k equal to 20.
- Values of k from 20-40 seem to be a good recommendation.

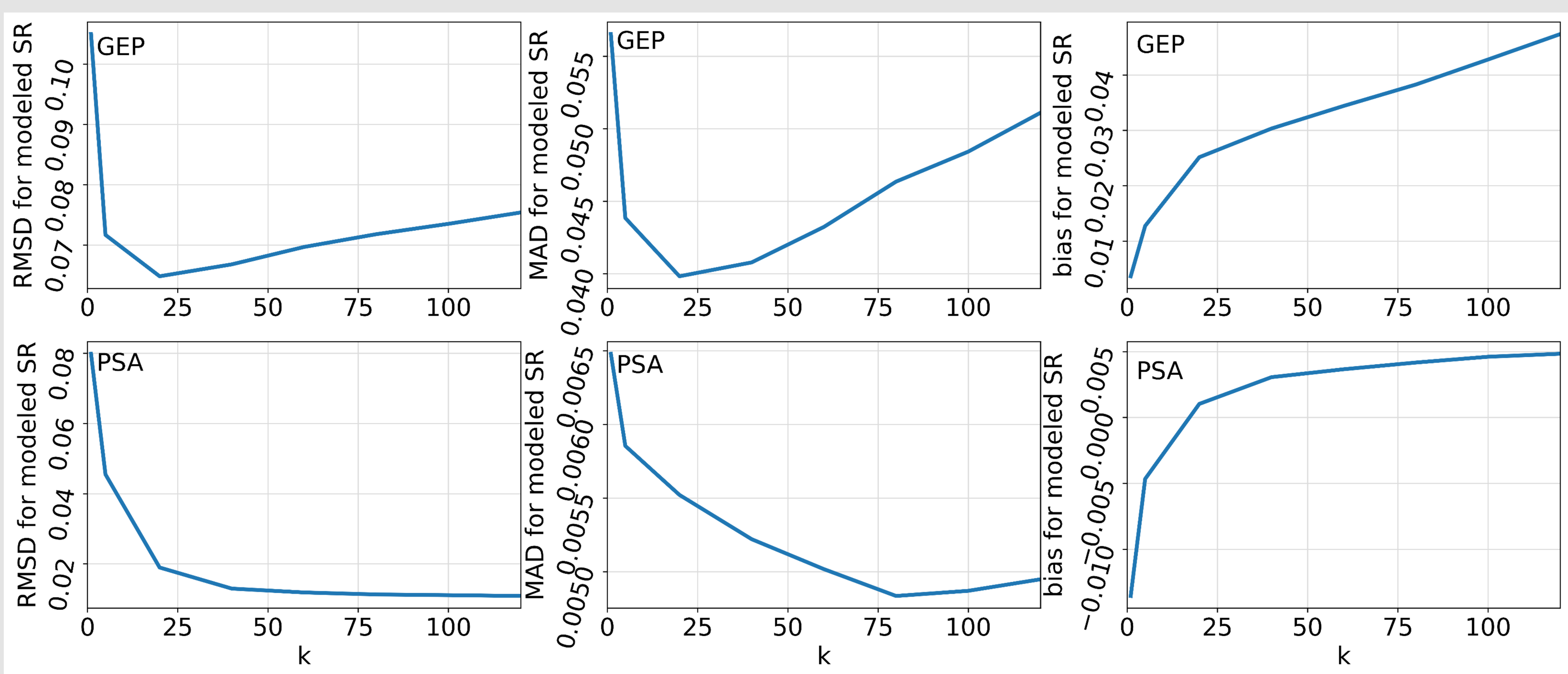

Figure 5: RMSD, MAD and bias of persistence model with precipitation for different k and all lead times up to 170 days. (upper plots: GEP, lower plots: PSA)

Conclusion and Outlook

- Considering natural cleaning by rain strongly improves the soiling persistence forecast.
- Optimal *k* is highly dependent on site and measurement period.
- For the GEP, the persistence model considering rainfall performs better than the Kimber model for lead times up to 31 days in terms of RMSD and MAD and in terms of bias at all lead times depending on the value of k. For the PSA, the persistence model outperforms the Kimber model at all lead times for most k values.
- The persistence model can be used as benchmark for soiling forecasting models and performs best for sites without regular extreme soiling events.
- Further investigation will be conducted on whether persistence with precipitation climatology can be a good benchmark model.

References

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